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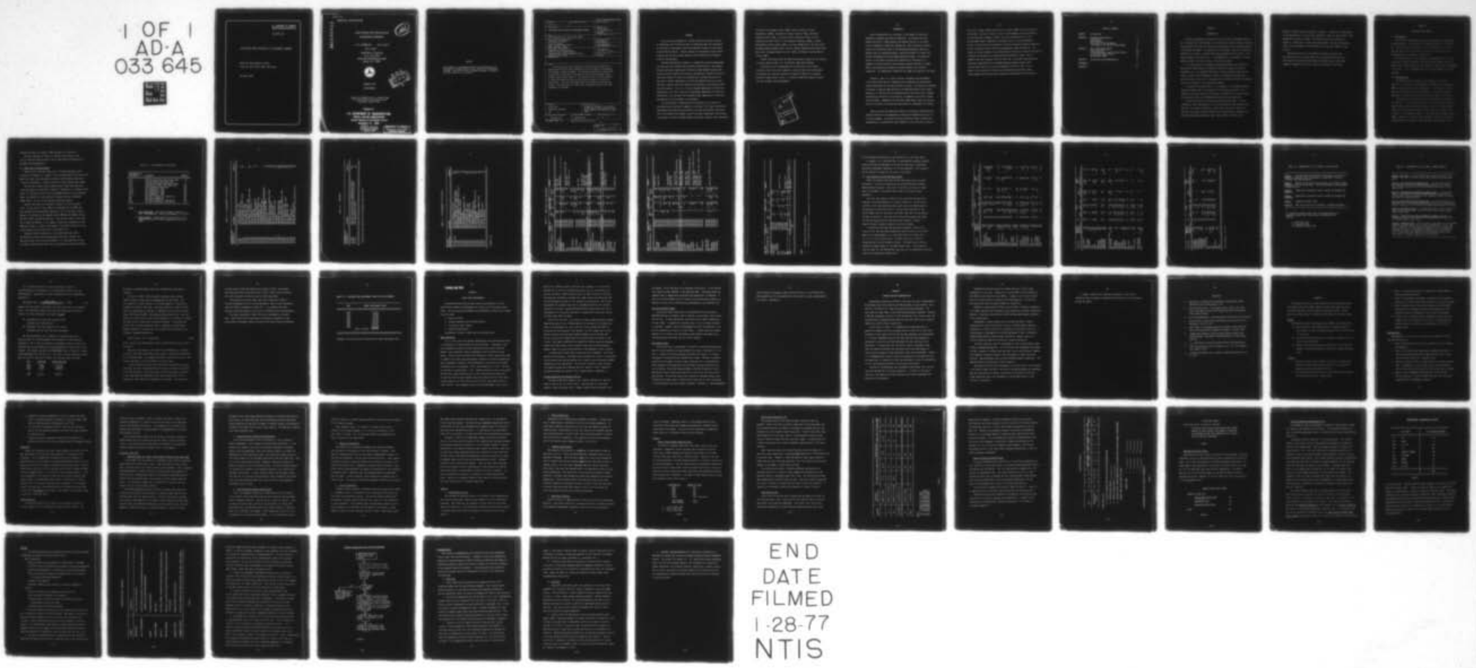

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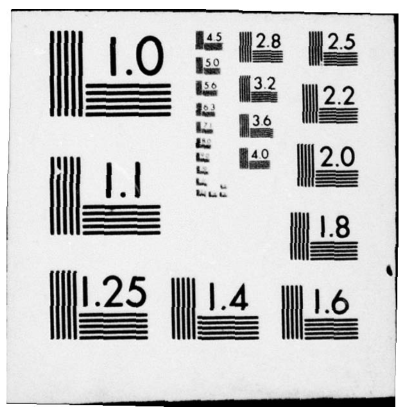
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VOR VACUUM TUBE AVAILABILITY ASSESSMENT PROGRAM

Rome Air Development Center
Griffiss Air Force Base, New York

October 1976

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Report No. FAA-RD-76-183

VOR VACUUM TUBE AVAILABILITY ASSESSMENT PROGRAM

G. K. Huddleston R.M. Cosel

W. D. Peele

Department of Defense
U.S. Air Force
Rome Air Development Center
Rome, N.Y. 13441

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Final Report

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16. Abstract

This report deals with the problem of the continued availability of vacuum tubes and solid state replacement devices to support representative VOR equipment through the 1980's. The reduced availability of vacuum tubes is due mainly to the massive transition to solid state equipment by the consumer entertainment industry. This action has led to a large reduction of vacuum tube suppliers, and to a significant increase in the cost of vacuum tubes. Price and tube demand data are presented for selected VOR systems. The applicability of solid state replacement devices to the VOR equipments is discussed.

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FOREWORD

This effort was conducted by Purdue University, Georgia Institute of Technology, and Florida Institute of Technology under the sponsorship of the Rome Air Development Center Post-Doctoral Program for the Federal Aviation Administration. Charles Andrasco of the Federal Aviation Administration was the task project engineer and provided overall technical direction and guidance.

The RADC Post-Doctoral Program is a cooperative venture between RADC and some sixty-five universities eligible to participate in the program. Syracuse University (Department of Electrical and Computer Engineering), Purdue University (School of Electrical Engineering), Georgia Institute of Technology (School of Electrical Engineering), and State University of New York at Buffalo (Department of Electrical Engineering) act as prime contractor schools with other schools participating via sub-contracts with the prime schools. The U. S. Air Force Academy (Department of Electrical Engineering), Air Force Institute of Technology (Department of Electrical Engineering), and the Naval Post Graduate School (Department of Electrical Engineering) also participate in the program.

The Post-Doctoral Program provides an opportunity for faculty at participating universities to spend up to one year full time on exploratory development and problem-solving efforts with the post-doctorals splitting their time between the customer location and their educational institutions. The program is totally customer-funded with current projects being undertaken

for Rome Air Development Center (RADC), Space and Missile Systems Organization (SAMSO), Aeronautical Systems Division (ASD), Electronic Systems Division (ESD), Air Force Avionics Laboratory (AFAL), Foreign Technology Division (FTD), Air Force Weapons Laboratory (AFWL), Armament Development and Test Center (ADTC), Air Force Communications Service (AFCS), Aerospace Defense Command (ADC), Hq USAF, Defense Communications Agency (DCA), Navy, Army, Aerospace Medical Division (AMD), and Federal Aviation Administration (FAA).

Further information about the RADC Post-Doctoral Program can be obtained from Jacob Scherer, RADC, tel. AV 587-2543, COMM (315)-330-2543.

The authors wish to acknowledge the contributions of Ray Gambill, Linda Ott, Virgil Chick, Bob Ledbetter, and Henry Shaw from the FAA Depot at Oklahoma City; Montford Locklear and Thomas H. Thomas of the Defense Electronic Supply Center; and Mr. J. Scherer of RADC Post Doctoral Program for their guidance and encouragement.

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BIOGRAPHIES

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Richard M. Cosel is a former Director of Research and Development in the specialized areas of communications, navigation and ground based radar surveillance for the United States Air Force. He received his Bachelor of Science in Business Administration with High Distinction from Indiana University in 1957 and has also attended Cornell University (E.E.), Modern Engineering at University of California, Los Angeles, and several related service schools. Memberships include Beta Gamma Sigma, Sigma Iota Epsilon, and he is a Fellow of the American Association for Advancement of Science.

Warren D. Peele was Associate Professor of Electrical Engineering and Executive Officer of the Department of Electrical Engineering at the U. S. Air Force Academy. He joined the Purdue University School of Electrical Engineering as a professional staff engineer in July 1971 after receiving

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CHAPTER I

INTRODUCTION

The FAA investigation of vacuum tube and solid state replacement devices for a selected set of VOR Systems is one facet of the larger problem of assuring the availability of tubes for FAA operating equipments with an expected usable life through the 1980's. The objectives of the present study are to assess the capability of industry to support VOR systems through this time period. This report addresses the problems of: (1) dependability of tube supply; (2) tube phase-out dates; (3) cost of tubes; (4) quality of tubes.

It is also required to recommend alternate approaches and to make the best possible determination of alternate methods of supporting existing equipment, e.g., (1) equipment modification so that available tubes can be used; (2) solid state replacement of tubes; (3) equipment modification to use solid state circuitry; (4) estimated cost of alternate methods; (5) assessment of the reliability of alternate approaches.

To accomplish the above tasks, it is necessary to investigate possible sources of vacuum tubes: the expected life of existing on-shore (U. S.) suppliers, off-shore (foreign) procurement, the value of the surplus market, the practicality and cost of DOD/FAA subsidizing tube manufacturers.

Toward these ends, the following actions have been taken. A cross reference of tube requirements vs. typical VOR types has been obtained from the FAA. The present availability, price data, and forecast demand for pertinent tube types has been obtained from the FAA Depot at Oklahoma City and from the Defense Electronic Supply Center (DESC) at Dayton, Ohio.

Analysis of these data are presented in Chapter 2. Preliminary investigations of the applicability of solid-state replacements (SSR) for vacuum tubes in VOR equipments have been initiated. The results thus far are presented in Chapter 3. Additionally, vacuum tube manufacturers have been contacted to obtain their assessment of the availability of tubes and changes in tube pricing.

Government concern for the problems that may be caused by the diminishing sources of vacuum tubes was first manifested officially in the formation of the DOD Ad Hoc Vacuum Tube Support Group in May 1973. Appendix A summarizes the report issued by that group in June 1975.

CHAPTER 2

VOR VACUUM TUBE ANALYSIS

2.1 Introduction

This chapter presents data concerning the vacuum tube requirements of VOR equipments. The equipments considered are presented in Section 2.2. The tube types and quantities used are presented in Section 2.3. Cost and usage data are presented in Section 2.4. Conclusions and recommendations are presented in Section 2.5.

The data presented in this chapter were collected from a variety of sources including FAA ARD-350, FAA Depot (OKC), Defense Electronic Supply Center (DESC), AMEX, and from a number of FAA personnel interviewed in the field. It is recognized that the raw data presented is not yet complete.

2.2 VOR Equipments

The VOR equipments considered in the analysis are listed in Tables 2-1, 2-2, and 2-3. The equipments listed are those examined by AMEX in correlating tube types to equipments. The equipment quantity figures were provided by the FAA (ARD-350). It is assumed that the equipments and quantities listed are relatively complete and current.

The equipments are classified into the three tables according to type numbers. It was originally thought that this procedure would also classify the equipments according to age. Since the FAA type numbers (Table 2-3) were issued beginning 12/31/58 (and CA type numbers prior to then), it is assumed that Table 2-2 lists the older equipments (pre-1959). However, the vintage of the equipments in Table 2-1 cannot be established on the same basis since the letter type designations for

transmitters appear to extend to 1966 (see Note 1 of Table 2-1).

The data presented in Tables 2-1 through 2-3 are based in the main on FAA Order 0000.7A dated 15 April 1974 (Index of FAA Electronic Equipment Type Designations).

2.3 Tubes Used in VOR Equipments

Table 2-4 lists the tube types used in the VOR equipments listed in Tables 2-1 through 2-3. Column 1 lists the type cited in the instruction books; the latest tube designation carried on the FAA Depot stock lists is given in parenthesis. Column 2 gives the current Federal Stock Number.

The next four columns give the quantitites of each tube type used in the equipments as classified in Tables 2-1 through 2-3. A "greater than" symbol (>) indicates that the data or equipment quantity was not complete; hence, the quantity of tubes required is greater than the calculated number shown. The last column indicates pertinent remarks.

Problem tube types are indicated in Table 2-4 by the horizontal lines. At this point in time, Table 2-4 indicates that the 3B28, 5Z3, 6A3, and 836 are non-procurable, obsolete, or not in the supply system. However, as indicated in the Remarks column, 3B28 has SSR 1N2637, 5Z3 has SSR CP117 (EDI), and 836 has SSR CP131. But the 6A3 (triode, 4-pin base) has no known replacement; it is, however, electrically equivalent to the 6B4G (octal base). In short, there appear to be simple solutions for the problem tubes listed in Table 2-4 at the present time.

Attention should be drawn also to the metal tubes 6L6, 6SF5, and 6V6 which currently have no manufacturing source. However, the equivalent glass tubes are being produced. It is believed that the use of a metal shield with the glass tube in applications requiring shielding

TABLE 2-1. VOR EQUIPMENTS (PRE-CA NOS.)

EQUIPMENT TYPE DESIGNATION	EQUIPMENT	QUANTITY
TV-1	230W VHF Omni-Range Transmitter (VOR)	56
TV-2	50W Omni-Range Transmitter (VOR)	-
TV-4	230W VHF Omni-Range Transmitter (VOR)	78
TV-7	Transmitter, Radio, VHF, 230W (VOR)	310
TV-8	VHF Transmitter 200W (VOR)	130
TV-12	VOR Transmitter, 200W	160
TV-19	VOR Transmitter, 200W	160
TV-27	VOR Transmitter, 200W	169
TV-31	VOR Transmitter, 200W	164
TUL	VHF Radio Transmitter (108-127 mc)	200
TUM	VHF Radio Transmitter	200
TUO	VHF Radio Transmitter (108-118 mc)	236
TUO-1	VHF Radio Transmitter (108-118 mc)	254

NOTES:

1. Prior-1966 Usage. Two letters, hyphen, number; e.g., TV-1. T=Transmitter, V=Very High Frequency (3 to 30 mc).

2. Older Practice. Three letters; first letter T (or R), second letter U=old UHF band (approximate current VHF band).

TABLE 2-2. VOR EQUIPMENTS (CA TYPE NOS.)

EQUIPMENT TYPE DESIGNATION	EQUIPMENT	QUANTITY
CA-663	Carrier Modulator, VHF	-
CA-665	Carrier Modulator, Driver	-
CA-694	Oscillator-Keyer Unit (1020 Cycle)	432
CA-1201	Monitor Amplifier (VAR)	-
CA-1295	Monitor Amplifier (VOR)	-
CA-1296	Audio-Oscillator-Keyer (VOR)	-
CA-1330	Power Supply, Frequency Stabilized (VOR)	200
CA-1340	Carrier Modulator Driver	-
CA-1341	Carrier Modulator	-
CA-1349	Locking Tone Keyer Oscillator	60
CA-1396	Voice Frequency Amplifier	-
CA-1402	Carrier Modulator Driver (ILS)	-
CA-1403	Carrier Modulator (ILS)	-
CA-1421	Voice/Code Reproducer (VOR)	-
CA-1426	Volume Control and Speaker Switching Unit	-
CA-1479	Voice-Code Reproducer (VOR)*	40
CA-1485	Monitor, VOR	58
CA-1486	Regulated Output Audio Amplifier (VOR)	38
CA-1564	VOR Test Signal Generator	450
CA-1567	Monitor Amplifier-VOR	61
CA-1568	1020 Cycle Oscillator (VOR)	218
CA-1575	VOR Monitor	71
CA-1589/A	Regulated Output Amplifier	2295
CA-1600	1020 Cycle Oscillator (VOR)	384
CA-1601	Regulated Output Audio Amplifier (VOR)	155
CA-1608	Monitor Amplifier, VOR	155
CA-1611	Carrier Modulator Driver (VOR)	325
CA-1612	Carrier Modulator (VOR)	325
CA-1616	VOR Monitor	163
CA-1628	VOR Test Generator	285
CA-1652	Monitor Amplifier (VOR)	80
CA-1765	VOR Monitor Equipment Input Selection Unit	84

TABLE 2-2. (CONTINUED)

EQUIPMENT TYPE DESIGNATION	EQUIPMENT	QUANTITY
CA-1782	Regulated Output Amplifier (TOWERSCENTERS,INSACS)	1575
CA-2946	1020 cps Oscillator (Converted CA-666)(VOR/DME)	-
CA-3410	VOR Counterpoise Detector	488

*Instruction books marked CA-1478; Equipment marked CA-1421A.

TABLE 2-3. VOR EQUIPMENTS (FA TYPE NOS.)

FA TYPE DESIGNATION	EQUIPMENT	QUANTITY
FA-5155	VOR Test Generator (VOR Test)	147
FA-5226/5303	VOR Monitor Equipment Input Selection Unit	205
FA-5238	Regulated Output Amplifier (TOWERS,INSACS)	618
FA-5257	VHF Omnirange Automatic Frequency Control Unit*	40
FA-5258	VOR Frequency Deviation Monitor*	20
FA-5328	VOR Test Generator	54
FA-5341	Voice/Code Reproducer Assembly (VOR)	40
FA-5412	Monitor Amplifier, VOR	114
FA-5414	Audio Oscillator Keyer (VOR)	597
FA-5416	VOR Carrier Modulator Driver	177
FA-5417	VOR Carrier Modulator	177
FA-5424	VOR Regulated Output Amplifier	114
FA-5427	VOR Monitor Equipment Input Selection Unit	191
FA-5428	VOR Test Generator	97
FA-5429	Voice/Code Reproducer Assembly (VOR)	136
FA-5612	VOR Monitor Amplifier	42
FA-5616	VOR Carrier Modulator Driver	87
FA-5617	VOR Carrier Modulator	87

*Doppler VOR

TABLE 2-4. TUBES USED IN VOR EQUIPMENTS.

TUBE TYPE (LATEST DESIGNATION)	CURRENT FSN 5960-00-	QUANTITY USED PRE CA	CA	FA	TOTAL	REMARKS
HK253	-188-8542	400	0	0	400	TUL only
HK454H(250TH)	-114-3826	400	0	0	400	TUL only
VR150(VR150-OD3)	-188-8573	0	60	0	60	CA1349 only
OA2(OA2WA)	-503-4880	783	2,085	1,806	4,674	
OB2(OB2WA)	-624-4718	366	> 464	1,358	> 2,188	
OC3	-188-0968	0	> 536	0	> 536	CA1330,1421,1478,1485,1486
1P39	-281-0798	0	40	0	40	CA1478 only
1P40	-235-9124	0	?	0	?	CA1421 only (1 ea.)
12AL5	-878-1881	0	617	418	1,035	
12AT7(12AT7WC)	-179-4446	0	3,572	0	3,572	
12AU6		444	8,682	4,060	13,186	
12AX7(12AX7WA)	-827-8782	0	> 5,593	1,544	> 7,137	
100TH	-116-9979	800	0	0	800	TUL only
2D21(5727)	-552-0082	0	> 296	156	> 452	
2E26	-188-8569	1,227	0	0	1,227	TV units only
217C	-615-5604	1,744	0	0	1,744	TUM,TUO only
2050(2050W)	-193-5129	0	> 1	0	> 1	CA1201 only
3B25(T10KV)	5961-00-506-9795	1,380	> 400	0	> 1,780	T10KV is SSR
3B28	-108-0252	508	> 750	528	> 1,786	*Non-procurable* SSR:1N2637
4B32(STR4B32)	-188-0944	2,454	0	0	2,454	STR4B32 is SSR
4CX250B(7203-4CX250B)	-892-0828	1,566	0	0	1,566	
4-65A(8165)	-958-9146	> 444	0	0	> 444	
4-125A(4D21)	-188-0921	1,888	0	0	1,888	
5R4(5R4WGB)	-681-9741	1,671	683	1,076	3,430	
5Y3(5Y3WGA)	-262-0218	0	> 1,192	927	> 2,119	
5Z3(?)	NO DATA AVAILABLE	0	?	0	?	CA665,1201 only. *Obsolete* CP117 EDI
5U4(5U4GB)	-642-8341	0	> 200	0	> 200	CA1330,1340 only
592	-063-1867	980	0	0	980	TUO,TUO-1 only
5651(5651WA)	-262-0286	0	116	402	518	
*5654(5654W)	-045-8639	333	0	120	453	
5670(5670W)	-134-5994	0	336	0	336	
5686	-237-0077	493	0	0	493	
*5725(5725W)	-134-6064	0	0	20	20	FA5258 only

TUBE TYPE (LATEST DESIGNATION)	CURRENT FSN 5960-00-	QUANTITY USED				REMARKS
		PRE CA	CA	FA	TOTAL	
5726	-879-5078	0	0	80	80	FA5258 only
5749(5749W)	-134-5004	0	0	800	800	
5750/6BE6W	-264-3002	0	0	60	60	FA5258 only
5751	-082-4139	0	1,176	6,444	7,620	
5763	-188-3915	> 290	0	0	> 290	
5814A	-262-0210	783	504	8,060	9,347	
5915	-262-0223	0	310	228	538	
6AK5(5654)	-045-8639	894	0	0	894	(See 5654 below)
6AL5(5726)	-134-9919	0	6,688	846	7,534	(-879-5078)
6AN5(6AN5WA)	-543-0219	0	0	40	40	FA5257 only
6AQ5(6005W)	-134-6073	0	296	156	452	
6AS6(5725W)	-134-6064	0	628	0	628	(See 5725 below)
6AS7(6AS7GA,6080WC)	-166-7674	0	116	0	116	CA1485 only. (See 6080 below)
6AU6(6AU6WC)	-179-3710	0	11,413	1,833	13,246	
6A3 (4 pin)	-617-8615	0	>?	0	?	CA665 only. *Non-procurable*
6B4(6B4G)	-188-3941	0	>?	0	?	CA1340,1402 only
6C4(6C4WA)	-557-6780	0	216	306	522	
6C5(6C5)	-188-8500	0	?	0	?	CA665,2946 only
6F6(6F6)	-188-8504	0	?	0	?	CA1201,2946 only
6H6(6H6)	-188-8499	0	> 38		> 38	CA1341,1396,1403,1426,1486 only
6J5(6J5WGT)	-228-3765	0	> 650	0	> 650	
6L6(6L6GC)	-262-0161	0	650	0	650	Metal Tube; 6L6GT is glass, use shield
6L7	-188-8527	0	> 76		> 76	CA1426,1486 only
6N7(6N7GT)	-100-5241	0	60	0	60	CA1349 only
6SF5	-615-5682	0	?	0	?	Metal Tube; CA1396 only; 6SF5GT is glass
6SH7	-989-1251	0	58	0	58	CA1485 only
6SJ7(6SJ7GT)	-617-4918	0	> 802		> 802	
6SL7(6SL7WGT)	-188-0883	0	> 78	0	> 78	
6SN7(6SN7GTB)	-804-0956	> 2	> 2,056	0	> 2,058	
6V6	-100-5893	> 136	> 832	528	> 1,496	Metal Tube; 6V6GTA is glass
6X4(6X4WA)	-272-9182	0	5,056	1,030	6,086	
6X5(6X5WGT)	-188-0926	0	> 60	0	> 60	
6Y6(6Y6GT)	-617-6097	0	> 80	0	> 80	
6080(6080WC)	-179-3252	0	168	820	988	

TUBE TYPE (LATEST DESIGNATION)	CURRENT FSN 5960-00-	QUANTITY USED PRE CA	CA	FA	TOTAL	REMARKS
*6136(6AU6WC)	-179-3710	0	0	3,236	3,236	
6146(6146B)	-904-9744	783	0	0	783	
(6146W)	-060-6565	-	-	-	-	
*6201(12AT7WC)	-179-4446	0	0	1,700	1,700	
805	-114-4881	0	> 400	0		CA663,1330 only
807	-114-4868	1,580	> 1	0	> 1,581	
811A	-189-5973	> 2	> 650	528	> 1,180	
826	-617-8540	980	0	0	980	TUO,TUO-1 only
829	-107-8147	> 1	0	0	> 1	TV-2 only
836	?	400	0	0	400	TUL only; SSR CP131 (EDI)
866A	SSR:5961-00-850-3003	> 4	> 2	0	> 6	SSR:1N2637

NOTES:

1. SSR means solid state replacement.

2. EDI is Electronic Devices, Inc., a manufacturer of solid state replacements for vacuum tubes.

will alleviate any problems with the availability of the metal tubes.

In summary, it is concluded that no insurmountable problems presently exist concerning the availability of specific tube types or applicable equivalent replacement components for the VOR equipments. The situation may be expected to change for the worse in the future.

2.4 Cost Analysis for VOR Tube Requirements

Table 2-5 presents cost data for most tube types used in the VOR equipments. The cost and usage data were obtained from the FAA Depot, General Material Section. Tube types for which no cost data are shown were not included in the demand inquiry made to the supply system computers.

The first two columns in Table 2-5 give tube types and quantities required in the VOR equipments as listed in Table 2-4. Column 3 gives the "CA" or "AC" code which describes supply source and demand velocity as explained in Tables 2-6 and 2-7. The next three columns give the FAA (or DESC) price of the tube in June 1974, June 1976, and the percent increase in the price. The last three columns give average tube usage for the two one-year periods and the percent increase in usage. A negative percent increase represents a positive decrease.

It should be noted that the usage data presented in Table 2-5 is valid only for the tube types stocked and issued exclusively by the FAA Depot to its FAA customers; i.e., tube types whose "AC" codes carry a 1, 3, or 4 in the first position. All other tube types listed are shipped directly to FAA customers by DESC. The demand inquiry did not capture the usage figures for the DESC-stocked items. (The usage data that are shown for the DESC-handled types apply to the usage data by the FAA shops at the Aeronautical Center only.)

TABLE 2-5. COST AND USAGE DATA FOR VOR TUBES

TUBE TYPE	QUANTITY REQUIRED (TABLE IV.)	AC	PRICE 6/74	PRICE 6/76	PRICE %↑	USAGE AVG. 6/74-5/75	USAGE AVG. 6/75-5/76	USAGE %↑
HK253	400			2.80				
HK454H(250TH)	400	34	28.03	51.00	82	20	23	15
VR150(VR150-003)	60	22	3.16	1.20	- 62	> 1	7	600
OA2(OA2WA)	4,674	23	.76	.80	5	> 1	120	11,900
OB2(OB2WA)	> 2,188	23	3.00	1.03	- 66	10	203	1,930
OC3W	536	23	2.44	3.76	54	1	6	500
1P39	40	22		1.80				
1P40	?	22		2.10				
12AL5	1,035	22	.50	.64	28	0	10	∞
12AT7(12AT7WC)	3,572	24	.68	.88	29	2,806	630	- 78
12AU6	13,186	22	.52	.55	6			
12AX7(12AX7WA)	> 7,137	14	.40	.72	80	2,218	1,877	- 15
100TH	800	14	24.40	36.40	49	77	66	- 14
2D21(5727)	452	23	.63	.99	57	209	56	- 73
2E26	1,227	23	3.19	4.14	30	> 1	49	4,800
217C	1,744	24	25.00	52.00	108	> 1	9	800
2050(2050W)	> 1	23	6.25	7.06	13	2	12	500
3B25(T10KV)	1,780		4.38					
3B28	1,786		4.24					
4B32(STR4B32)	2,454	23	6.67	8.10	21	289	14	- 95
4CX250B	1,566	34	14.87	17.49	18	789	718	- 9
4-65A(8165)	> 444	24	16.10	23.70	47	1	49	4,800
4-125A(4D21)	1,888	24	36.60	37.20	2	202	44	- 78
5R4(5R4WGB)	3,430	24	6.01	8.25	37	199	52	- 74
5Y3(5Y3WGTA)	> 2,119	23	.40	3.10	675	1	58	5,700
5Z3	?							
5U4(5U4GB)	> 200	22	.53	.66	25	4	11	175
592	980	34	43.57	43.57	0	137	117	- 15
5651(5651WA)	518	23	.64	.79	23	3	97	3,133
5654(5654W)	453	34	.91	1.11	22	9,016	7,240	- 20
5670(5670W)	336							
5686	493	23	2.36	2.26	- 4	> 1	23	2,200

TUBE TYPE	QUANTITY REQUIRED (TABLE IV.)	AC	PRICE 6/74	PRICE 6/75	PRICE %↑	USAGE AVG. 6/74-5/75	USAGE AVG. 6/75-5/76	USAGE %↑
5725(5725W)	20	14	.79	1.20	52	1,406	1,331	- 5
5726	80	14	.60	.73	22	1,815	1,454	- 20
5749(5749W)	800			.73				
5750/6BE6W	60	23	.92	.97	5	220	44	- 80
5751	7,620			.82				
5763	> 290	23	.86	.96	12	687	121	- 82
5814A	9,347	14	.62	.74	19	2,385	2,067	- 13
5915	538	23	.85	1.23	45	1	28	2,700
6AK5(5654)	894							
6AL5(5726)	7,534							
6AN5(6AN5WA)	40	14	1.70	1.47	- 14	851	1,591	87
6AQ5(6005W)	452	23	.76	.88	16	1	221	22,000
6AS6(5725W)	628							
6AS7(6AS7GA,6080NC)	116	14	2.10	5.61	167	943	762	- 10
6AU6(6AU6WC)	13,246	14	.64	.78	22	2,574	2,538	- 1
6A3	?	72		1.00				
6B4(6B4G)	?	22	5.80	4.23	- 27	0	3	∞
6C4(6C4WA)	522	23	.63	.80	27	> 1	46	4,500
6C5(6C5)	?	22	1.29	1.29	0	0	3	∞
6F6(6F6)	?	23	1.10	2.18	98	96	17	- 82
6H6(6H6)	738	23	8.40	1.06	- 87	0	22	∞
6T5(6J5WGT)	> 650	23	.80	3.63	354	0	20	∞
6L6(6L6GC)	650							
6L7	> 76	23	1.81	2.06	14	21	4	- 81
6N7(6N7GT)	60							
6SF5	?	72	.91	1.59	75	11	6	- 45
6SH7	58	22	1.29	1.43	11	0	1	∞
6SJ7(6SJ7GT)	> 802	31	?	2.00				
6SL7(6SL7WGT)	> 78	23	1.73	1.77	2	0	15	∞
6SN7(6SN7GTB)	> 2,058	34		.86				∞
6V6	> 1,496	21	1.44	1.65	15	1	14	1,300

TUBE TYPE	QUANTITY REQUIRED (TABLE IV.)	AC	PRICE 6/74	PRICE 6/76	PRICE %↑	USAGE AVG. 6/74-5/75	USAGE AVG. 6/75-5/76	USAGE %↑
6X4(6X4WA)	6,086	23	.53	.50	- 6	1	138	13,700
6X5(6X5WGT)	> 60	22		1.64				
6Y6(6Y6GT)	> 80	22	.89	1.14	28	0	3	∞
6080(6080WC)	988	14		5.61				
6136(6AU6WC)	3,236	14		.78				
6146(6146B)	783	21	2.78	3.03	9	10	1	- 90
or(6146W)		23	1.60	3.56	123	431	96	- 78
6201(12AT7WC)	1,700	24	.68	.88	29			
805	?	14	14.50	24.30	68	92	81	- 12
807	> 1,581	23	3.65	4.30	18	> 1	34	5,300
811A	> 1,180	14	3.16	5.33	69	933	783	- 16
826	980	14	7.00	36.18	417	57	57	0
829(829B)	> 1	24	14.50	18.30	26	2	61	2,950
836	400							
866A	> 6							

Total Quantity: >121,773

TABLE 2-6. EXPLANATIONS OF "AC" COLUMN - FIRST POSITION

Group 1. Procured wholesale from DESC and shipped to the Depot for technical evaluation prior to placement in depot stock; issued to customers from Depot Warehouse.

Group 2. DESC direct ship to field facilities, but stocked in Depot warehouse for issue to FAA shops. Stock levels based on local demand/ consumption only.

Group 3. Commercially procured by Depot; stocked and shipped from warehouse.

Group 4. Commercially procured by Depot; stocked and shipped from warehouse.

Group 6. Exchange and Repair item.

Group 72. DESC direct ship to all customers, including FAA shops.*

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*"7" identifies planned direct ship. The second position (2) identifies supply source (DSA) rather than demand dollar velocity.

71 = GSA Direct Ship
72 = DSA Direct Ship
73 = Commercial Direct Ship.

TABLE 2-7. EXPLANATION OF "AC" COLUMN - SECOND POSITION

Group 1. New Items. In system under three years from date of first receipt, with less than three average annual demand transactions per year.

Group 2. Low Value/Velocity Demand Items. In system three years or more from date of first receipt and/or with three or more average annual demand transactions, and the forecasted demand value is less than $250.00.

Group 3. Intermediate Value/Velocity Demand Items. In system three years or more from date of first receipt and/or with three or more average annual demand transactions, and forecasted demand value ranges from $250.00 through $5,000.000.

Group 4. High Value/Velocity Demand Items. In system three years or more from date of first receipt and/or with three or more average annual demand transactions, and the forecasted demand value exceeds $5,000.000.

Group 5. Slow Moving Items. In system three years or more from date of first receipt with at least one, but less than three average annual demand transactions.

Group 0. Items With Less Than One Demand Transaction Per Year. In system three years or more from date of first receipt with less than one demand transaction per year.

Group 6. Insurance Items. Items for which a requirement is not normally expected, its need usually being caused by unpredictable events; the item is essential; and the lead time required to obtain the item when needed would create an unacceptable situation such as a stoppage of essential operations or existence of a condition hazardous to human life. Newly provisioned items meeting the insurance criteria are identified as "insurance" upon entry into the system.

It is further noted that the valid usage data in Table 2-5 includes usage by all equipments in the FAA inventory and not just the VOR equipments. Consequently, no tube replacement rate can be determined according to

$$\text{Replacement Rate} = \frac{\text{Normal Usage}}{\text{Total Quantity Required}} \times 100\% \qquad (2\text{-}1)$$

because the total quantity required of any given tube type is not presently known. This observation leads to the important conclusion that the calculation of a tube replacement rate requires either:

(1) Knowledge of the total tube usage and total equipment tube requirements; or

(2) Knowledge of the tube usage for just the VOR equipments and the total VOR tube requirements.

The tube replacement rate is important in estimating the cost of replacing tubes in the VOR equipments (and eventually in other tube-type equipments). Due to lack of information, replacement rates will have to be estimated and the corresponding costs computed based on a known rate of price increase. For example, consider the HK454H(250TH) tube in Table 2-5. Assume a 10% replacement rate per year; i.e., .10 x 400 = 40 tubes required per year. Based on a 35% per year price increase, the following costs are found:

Year	Cost/Tube	Annual Tube Cost
1974	28.03	$ 1,121.20
1975	37.84	1,513.62
1976	51.00	2,040.00
⋮	⋮	⋮
1986	1,024.03	40,961.11

Of course, a constant 35% per year price increase may or may not be realistic.

The data in Table 2-5 may be used to estimate a more accurate annual increase in tube price as averaged over the tube types. The total quantity of tubes required by the VOR equipments is >121,773 and includes 76 different tube types. The total quantity of tubes for which 6/74 price information is available is 100,809; the total worth of these tubes in 6/74 was $338,984. The average tube worth was $3.36. The total quantity of tubes for which 6/76 price information is available is 121,425; the total worth of these tubes in 6/76 was $503,406. The average tube worth at this time was accordingly $4.15. Assuming a constant annual percent increase in tube price for the two-year period, the annual price increase is computed according to

$$(6/74\ \text{Price})(1 + x)^2 = (6/76\ \text{Price}) \qquad (2\text{-}2)$$

to be 11.1% per year (approximately equal to the inflation rate for these two years!).

When only those tubes for which 6/74 price information is available are used in the 6/76 calculations, there results a total worth of $466,392 for the 100,809 tubes. The average tube worth in this case is $4.63. This figure translates to a price increase of 17.4% per year.

A third estimate of tube price increase may be obtained by averaging tube worth over only those types which are used in the smaller quantities in the VOR equipments. When those types for which the quantity required is less than 1000 are considered, there results 12,819 tubes in this category for which 6/74 price information is available. The total worth

of these tubes in 6/74 was $103,742 and $153,225 in 6/76. The average tube worth was $8.09 in 6/74 and $11.95 in 6/76. These figures translate to a price increase of 21.6% per year for these tube types.

If one uses the 17.4% per year tube price increase and assumes a 10% tube replacement rate for the VOR equipments, then the tube replacement costs are found as presented in Table 2-8. It is expected that these costs are miniscule compared to the costs of replacing entire VOR equipments.

The figures presented in TAble 2-8 must be considered as estimates only. Other factors could cause drastic increases or decreases in tube prices and/or replacement rates which would alter these figures considerably.

TABLE 2-8. ESTIMATED TUBE REPLACEMENT COSTS FOR VOR EQUIPMENTS.

YEAR	ANNUAL REPLACEMENT COSTS*
1976	$ 50,341
1977	59,100
1978	69,384
1979	81,457
1980	95,630
1981	112,270
1982	131,805
1983	154,739
1984	181,663
Total (8 years)	$936,389

*Assumes 17.4% per year price increase and 10% tube replacement rate.

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CHAPTER 3

SOLID STATE REPLACEMENTS

Considerable advertising has been done by the proponents of solid state devices offered as replacements for scarce or non-procurable vacuum tubes. From an application standpoint the replacement problem can be divided into four areas:

1. Power rectifiers
2. Voltage regulators and reference devices
3. Low current signal diodes
4. Amplifiers/oscillators

The problems involved in each area are discussed below.

Power Réctifiers

It is in this area that numerous manufacturers are offering direct plug in replacements for high voltage tube type rectifiers. References 1 and 2 are representative catalog listings showing the wide variety available. However, the terminology 'direct replacement' must be examined in some detail. While silicon rectifiers with voltage and current capabilities equal to commonly used high vacuum and gaseous rectifiers are widely available and easily packaged to conform to tube configuration, significant and inherent differences must be considered. First, the forward drop is less. The drop per junction is approximately 1 volt. Gaseous rectifiers such as the type 83 and 872 have a peak voltage drop of 10 volts (approximately) Reference 3. On the other hand the more commonly used high vacuum rectifiers will show a voltage change of up to 60 volts from half to full load (5U4G, capacitor input filter). Thus, plugging a direct silicon replacement into a circuit

calling for a 5U4G can cause significant over voltages. This can be compensated for by the use of dropping resisters, but, it must be done on a case by case basis, examining each circuit for load and type of filtering, selecting the resistance to provide the proper drop at the operating load. The FAA Aeronautical Center is well abreast of the situation. Solid state replacements for gaseous tubes such as the 4B32 and 872 are now routinely supplied to the field. Appropriate modification instructions with plug in replacements are also being furnished for installations using types such as the 5Y3G, 5Z3G, 5R4G, and 5U4G.

The silicon rectifier is an instant on device, supplying output voltage immediately upon turn on. Voltage applied to the plates of non conducting tubes in the equipment can, over a period of time, degrade the tubes by stripping the oxide coating of the cathode. For this reason many circuits employ rectifiers with indirectly heated cathodes such as the 6X4, 6X5 so that the rectifier cathode heats at the same rate as the others in the circuit. Here again installation of protective circuitry would be necessary. Simple time delay devices such as thermal relays can provide protection. However, again on a case by case analysis of the equipment circuit involved.

It should also be noted that ratings must not be exceeded. Solid state devices are unforgiving. Overloads, even transients can result in catastrophic failure whereas tube devices generally will sustain severe overloads, perhaps degrading but still operational. The 872 with a nominal current rating of 1.25 amperes average and 5 amperes peak will sustain a 'fault' maximum of 50 amperes maximum for duration of 0.2 seconds maximum. Reference 3.

<u>Voltage Regulators and Reference Devices</u>

The zener diode would appear to be a logical candidate for replacing tubes in the OA, OB, OC, and VR series. They are made in a wide power capacity range and voltage steps. However, again serious constraints must

be imposed. First, the zener is an excellent noise source. In the 100-150 volt range the zener operates in the avalanche mode. (Avalanche diodes are commonly used in commercially available noise generators.) Furthermore, if used in an RF environment such as a radar, stray pulsed energy picked up by adjacent circuits can be rectified and superimposed on the regulated line.

Low Current Signal Diodes

Low current signal diodes such as the 6AL5/12AL5 and more obsolete 6H6/12H6 families are commonly used in detector, discriminator, AGC circuits and the like. In most applications these tubes can be readily replaced by silicon diodes. A commercially available plug in unit to replace the 6AL5 is available. However, again interchangeability across the spectrum of use must be examined on a circuit by circuit basis. In most cases the simplest approach is to directly wire the diodes across existing tube socket pins, selecting appropriate diodes for the circuit involved.

Multielement Tubes

Solid state plug in replacements for specific triodes and pentodes have been in a mass production for approximately four years. References 4, 5, 6, and 7. Junction Field Effect devices have been used singly or in cascade arrangement to approximate both pentodes and triodes. However, in practice production units appear to have an upper frequency limit of approximately twenty megahertz and characteristics which make them questionable for use as oscillators. Tests have been performed by the FAA Aeronautical Center, Reference 8, which indicates unsuitability in front end, oscillator and IF applications. On the other hand, units tailored to telephone company specifications are widely used to replace vacuum tubes used at audio frequencies in line amplifiers and other terminal equipment. Reference 5. New developments

should extend the frequency range of the device and it is anticipated that power capability will be increased from the current 3.5 watts (approximately) to 10 watts. Reference 9.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Approximately seventy-six different tube types are used in approximately 66 equipment types which comprise the VOR navigation systems studied. More than 121, 773 tubes of all types are required by these equipments. The total worth of these tubes in June 1976 was approximately $503,406. Assuming a 10% tube replacement rate and a 17.4% increase per year in tube prices, the estimated cost of maintaining the VOR's over the next eight years is approximately one million dollars (tubes only).

At this point in time, it is recommended that additional data be obtained to complete the cost and usage entries in Table 2-5 so that final estimates of tube usage and prices for the VOR equipments can be determined. It is further recommended that all FAA tube types and FAA equipments be correlated so that the total FAA requirement for each tube type can be determined. In conjunction with this effort, data on FAA-usage of each tube type should be obtained and correlated with total requirements so that accurate estimates of tube replacement rates can be determined. Finally, it is recommended that these cost data be projected and correlated with the estimated costs of replacing the tube type equipments so that the desirability of this and alternative courses of action may be determined.

The bulk of the VOR vacuum tube replacement requirements fall into the rectifier and amplifier oscillator categories. As noted, in the case of rectifiers, FAA depots are already shipping solid state replacements and modification instructions.

Consideration should be given to expanding the use of solid state replacements in this area. Commercially, the type 866 is being replaced by the IN2637 and the type 83 by the IN2634. A number of solid state replacements are routinely used in television CRT anode supplies. In each case, the substitution should be depot checked for suitability.

Because of the peripherial effects, use of zeners as general replacement for voltage regulators and reference voltage tubes does not appear economically feasible. Problems of shielding and noise filtering would require extensive circuit modification.

Replacement of signal diodes such as the 6AL5 and 6H6 in clipper, clamping and low level rectification circuits in VOR equipments should be considered as a logical follow on to replacement of the power rectifiers. A 'direct'pplug in replacement for the 6AL5 designated TR 1002 is offered by Teledyne Semiconductor, Mountain View, California. However, again, its circuit suitability should be verified on a case by case basis.

The least promising area for replacement is that of multielement tubes, triodes, tetrodes and pentodes. At first glance, JFET technology would appear to offer a capability without requiring major circuit modifications. However, the frequency limitations severely limit application in other than audio circuits. New developments could provide extended frequency capability. This approach should be monitored for future potential.

Application of solid state replacements for vacuum tubes is well underway in the area of power rectifiers, the area of voltage references and regulators does not look promising, further investigation is advisable in the small signal diode area and in the replacement of multielement tubes in other circuitry is advisable.

In summary, based on the information available, we can find no substantive data to support a conclusion that tubes will not be available through the 1980's.

References

1. Semicon Inc., 10 North Avenue, Burlington, Massachusetts, 01803. Solid State Devices Catalog, pages 24, 25.

2. Electronic Devices Inc., 21 Gray Oaks Avenue, Yonkers, New York 10710. Data Sheets for Solid-Tube[R] Industrial Rectifier Tube Replacements (also Television).

3. RCA Transmitting Tubes, Technical Manual TT5 (1962) pps 118 and 153, 154.

4. Burman, Bruce, Vacuum Tubes Yield Sockets to Hybrid JFET Devices, Electronics. April 10, 1972.

5. Meier, Albiu R., Solid State Substances for Electron Tubes Bring New Life to Old Communications Equipment, Telephony. April 29, 1974.

6. Teledyne Semiconductor, 1300 Terra Bella Avenue, Mountain View, California 94040. Data Sheet for TS6AK5 Solid State V cuum Tube Replacement.

7. ____, Data Sheet for TS12AT7 Solid State Vacuum Tube Replacement.

8. Private Communication with R. Ledbetter, FAA - AAC 453, Oklahoma City, August 5, 1972.

9. Private Communication with L. Wallick, Teledyne Semiconductor, June 25, 1976.

APPENDIX A

This appendix consists of data extracted from the DOD AD HOC Vacuum Tube Support Group Final Report dated June 1975 which appear pertinent to the FAA VOR Vacuum Tube Availability Assessment Problem. Persons desiring a broader scope of information should refer to the above report.

Purpose

The DoD Ad Hoc Vacuum Tube Support Group (DVTSG) was established to:

(a) identify specific tubes presently out of production and/or in short supply, as well as those anticipated to be in this position in the future;

(b) determine equipment applications, projected equipment life, and rate of tube replacement;

(c) develop practical and economical alternatives to the worsening problem of diminishing production sources for needed replacement tubes.

Findings

1. Allegations concerning the impact of the lack of manufacturing sources for vacuum tubes and the inability to take prompt and appropriate actions are essentially true.
2. No single technical solution exists for ameliorating the problem of diminishing sources for vacuum tubes.

3. There is no governing procedure for gathering the data needed to determine appropriate action.

4. There is no management requirement for determining the remaining inventory life of end article applications for most receiving tubes.

5. Prompt identification of end article application and forecasted remaining life of equipment furnished in accordance with international FAA security agreements is not currently practicable.

6. A central file to contain end item application data for all consumable items is not feasible at this time. File space and procedures may permit construction and maintenance of a file of selected items.

Recommendations

Recommendations 1-4 are short term actions, the remainder are long term continuing efforts.

1. Issue a DoD Directive specifying the responsibilities of affected DoD Components.

2. Issue a joint DSA/Military Departments implementing document to institute improved procedures for addressing each lack of manufacturing source problem for consumable items.

3. Generate a temporary Code to prevent disposal of needed consumable items. Subsequently, create a separate code symbol compatible with the definition of the problem of lack of manufacturing source.

4. Convene a joint OSD/DSA/Military Department Group to guide actions necessary to include improved practices into forthcoming automated materiel management procedures.

5. Develop and institute procedures for last buy funding and guidelines for requesting funds to subsidize or otherwise support COCO, GOCO, or GOGO consumable item production facilities.

6. If justified by an economic analysis, create an end item application file for selected consumable items and institute procedures for maintaining it.

7. Integrate improved procedures for dealing with problems of no manufacturing source into future automated materiel management process.

Background

Vacuum tube technology, now almost three quarters of a century old, has been supplanted by the ubiquitous semi-conductor and integrated circuit technology. Yet, the Department of Defense and the Civil Agencies of Government have a large inventory of tube powered equipment which will still operate satisfactorily as long as replacement tubes are available. Funds for modernizing or replacing all this equipment are unlikely to become available in the foreseeable future in this period of severe budget austerity. With the disappearance of the market for tubes for the original equipment manufacturer (OEM), the replacement market itself is insufficient to support profitably all of the vacuum tube manufacturing companies. Of the approximately two dozen major tube manufacturers which existed twenty years ago, no more than a half dozen survive today. This problem is particularly acute in the area of receiving tubes.

Study Objectives

The DVTSG was established to identify the magnitude and impact on military capability of the diminishing production source problem. The

initial plan was to conduct a survey to identify the specific tubes out of production permanently or likely to be in the near future and to determine the end item equipment application. It was expected that a pattern would emerge which would lead to the development of recommendations for practical and economical actions.

As the group gained insight into the nature of the overall problem, it became evident that the original plan was not likely to yield the desired results. The resultant actions undertaken by the DVTSG as the underlying problems became more evident and appear later in this appendix.

Situation within DoD

1. Receiving tubes not readily identifiable in Federal Stock Class 5960

It was evident that the conduct of a meaningful survey would be impossible without some clear definitions of terms. Some considered the terms "vacuum tube," "electron tube," and "receiving tube" to be synonomous. Others disagreed. The DVTSG eventually settled on the term "receiving tube" and accepted the definition which included those negative grid electron tubes whose anode dissipation did not exceed 50 watts, and low power rectifier tubes (under 250 watts). This definition covered the vast majority of tubes that were the products of the "receiving tube" industry.

As the DVTSG examined published listings of electron tubes which had previously been declared "non-procurable," it became evident that the lists contained more than just receiving tubes. Further investigation disclosed that previous recommendations to sub-classify Federal Stock Class (FSC) 5960, Electron Tubes, with additional descriptors such as receiving tube, klystron, magnetron, transmitting tube, etc. had been rejected. Thus, the listings

included not only those tubes which were products of the declining receiving tube industry but also those that the last manufacturing source had discontinued production for any one of a number of possible reasons, not necessarily related to the plight of the receiving tube industry. FSC 5960 also contains tube related hardware items.

2. No central file on end article application

The Military Departments differ significantly in their approach to materiel management. Their responses reflected these differences. It was evident that, whatever the intent of the materiel management philosophy used by a Military Department, none could rapidly respond to a request for comprehensive current application data. Nor could they promptly provide a life cycle forecast for all equipment applications that were identified. This is not to say that no data existed. Responses ranged from literally no answer to extensive lists of application data. A similar situation existed for requests for forecasts of the expected remaining life of end article equipment applications. In those instances where files had been created, they were not all inclusive and often had not been subsequently maintained. Thus, end item application data files, when available, were fragmented, incomplete and out of date.

3. Reutilization philosophy inappropriate

There were repeated allegations of needed tubes being furnished by surplus dealers whose stock had originally been purchased from government surplus disposal operations. This was due to a number of reasons. First, the value of excess tubes, carried at the procurement cost rather than replacement cost, was generally below the threshold ($300) for reporting back to the consumable item manager. Often tubes would be part of a miscellaneous lot of materiel declared excess. If not identified as Class A

condition (unused, in original marked container) the tubes were not reported to the inventory manager.

Other anomalies exist. For example, if usable surplus stock is offered to an integrated manager, it is likely to be refused is a six-year stock is on hand. Yet, the last buy program is proceeding on the basis of acquiring a ten-year stock.

4. Uncertain coordination

The interests of the materiel management and supporting elements was not always in consonance with the requisitioners' interests. Forecasts of impending stock outs are transmitted to Headquarters elements in the Military Departments, not the requisitioning activities. Later, actual stock-outs resulted in cancelled requisitions, which were returned to the requisitioning activities. Headquarters elements were not notified. Thus, within the Military Departments the degree of coordination of the information furnished by DESC is dependent upon the procedures which the Departments had instituted. In most instances, those coordination procedures were informal at best. The resulting information exchange, therefore, was uncertain.

5. Lack of credibility

Through a variety of means, the Defense Electronic Supply Center (DESC) had attempted to alert its customers of any forthcoming problem resulting from diminishing production sources. This had not always proved helpful. For example, customers would be notified that a tube is or was expected to be "non procurable." The customer and/or the engineering support activity would respond by providing DESC with the names of distributors, surplus dealers, jobbers and other secondary sources of tubes. Often DESC already

knew these sources and also knew that the lineage, age, life, and quality of such stock was suspect. The confusion was compounded because many did not realize that the term "non procurable" was intended to mean "not currently available from a manufacturing source." A tube declared "non procurable" might still be available in limited quantities from non-manufacturing sources.

Personnel in the Military Departments became increasingly skeptical. They did not believe the seriousness of the impending tube shortage problems. One spokesman constantly referred to it as an "alleged" problem. Previous declarations by the Defense Electronic Supply Center that certain tubes had, or would soon, become unavailable had rarely resulted in actual stock outs. The DESC usually took whatever extraordinary action was necessary to obtain an adequate supply from returns and non-manufacturing sources. Although successful from a mission effectiveness point of view, these activities which were carried out after a declaration of likely inability to satisfy future requisitions, impaired DESC's credibility with its customers. As these non-manufacturing sources are depleted, the problem becomes more acute. Despite the increasing urgency of the situation, effective action was often stymied by this increasing skepticism.

Industry

1. Lost Economy of Scale

The Chairman and Technical Advisor of the DVTSG visited manufacturing facilities of three major receiving tube producers to verify information presented. They found that the economies of scale resulting from a mass market were being lost. Tube prices were escalating rapidly because certain irreducible fixed costs had to be spread over a rapidly declining sales quantity.

2. Parts Availability

Contractors also suffered parts availability problems. In some cases, only a single supplier remained to furnish vitally needed components. In other cases, offshore sources had to be utilized when domestic sources no longer existed. Subcontractors to the tube industry also suffered from the same rapid escalation in costs as their sales volume diminished in relation to the fixed costs of operation. Yet, despite the rapid price escalation, few in the industry report adequate profits, if any at all.

3. Industry Consolidation

Each member of the industry is attempting to consolidate in order to continue to survive. Plants are being shut down, equipment moved or sold, employees furloughed. One plant had a factory work force that averaged 28 years of company service and no factory employee with less than 17 years of company service. All less senior employees had been laid off previously. Also, each of the major tube manufacturers is an operating division of a corporate conglomerate. The decision as to the continued existence of these, marginally profitable tube manufacturing operations emanates from corporate headquarters. Many expressed concern that operations which do not meet corporate standards of profitability would be closed. Also, the retirement of certain individuals means that needed critical skills are being lost with little hope of training any youthful replacements.

4. Proprietary Planning

Industry disarray is aggravated even further by the lack of coordinated planning. "Long range" planning is considered proprietary information because of the marketing advantages a competitor would have if he knew another's

future intentions. Therefore, there is little advance notice of any significant action that would erode one manufacturer's remaining market to the benefit of another. Any joint actions undertaken by competitors would likely be in violation of the Anti-Trust Statutes.

Actions

Identify DESC Managed Receiving Tubes

An analysis of Federal Stock Class (FSC) 5960, Electron Tubes was undertaken. Management records indicated that the Defense Electronic Supply Center (DESC) managed 6,724 National Stock Numbers in FSC 5960. Of these 4,045 were classified as "electron tubes." Because of the lack of sub-classification, the DESC managed population of receiving tubes had to be identified manually. This was accomplished by knowledgeable specialists who could classify tubes either by their personal familiarity or the use of Electronic Industry Association (EIA) type coding and associated published tube characteristic information. The number of DESC managed receiving tubes was eventually fixed at 941 (Figure 1).

REGISTERED TO	NUMBER OF TYPES
ARMY	701
NAVY	773
USAF	857
USMC	369
FAA	650
OTHER	839 (6 NO DOD)*
DESC MANAGED	941**
OTHER MANAGED	142***

* AS OF 6 APRIL 1974
** AS OF 6 MAY 1974
*** AS OF 30 MAY 1974

FIGURE 1

Verify "Non-Procurable" List

The original group of 136 "non-procurable" receiving tubes was examined. Many of the tubes originally identified an "non-procurable" had to be reclassified due to Sylvania's willingness to undertake one last consolidated run of all needed "Loctal" type tubes. "Loctal" type tubes represented about half of the total types of "non-procurable" receiving tubes. ("Loctal" tubes are those that lock into their socket. The design was said to have originated for use in early automobile radios. Sylvania is the sole supplier).

Other tubes also had to be reclassified due to the willingness of a small west coast manufacturer to undertake the production of limited quantities of selected tubes. Whereas, a volume manufacturer might expect upwards of 3,000 tubes per shift from each production line, this supplier's total plant capacity is estimated at 2,000 tubes per month.

The situation was further clouded by additions and deletions as preferred versions of a family of tubes changed with availability in the secondary market or government-owned shelf stock. The non-procurable tubes were categorized by projected stock out date. Stock out forecast categories of 3 years, 3-5 years, 5-10 years and more than 10 years were selected. A summary of the resultant migration of categories is shown in Figure 2.

Application Survey

One of the first actions was to request end item application data for the "non-procurable" tubes. After some initial confusion due to imprecise terminology, the survey was undertaken. The results, were inconclusive. One Military Department furnished some data promptly and was months late

CATEGORY	PROJECTED STOCK OUT DATE	NUMBER OF ITEMS				
		11 SEPT 1973	5 SEPT 1974	10 DEC 1974	21 MARCH 1975	24 APRIL 1975
I	WITHIN 3 YEARS	31 3/	68 1/	56 2/	43 6/	48
II	WITHIN 3 TO 5 YEARS	12 4/	28	24	15	15
III	WITHIN 5 TO 10 YEARS	95 5/	55	59	55	62
SUB TOTALS	(CATEGORIES I-III)		151	139		125
IV	BEYOND 10 YEARS		181	189		202
TOTALS	(CATEGORIES I-IV)		332	328		327

NOTES:

1/ NO ASSETS FOR 17 ITEMS
2/ NO ASSETS FOR 15 ITEMS
3/ LESS THAN ONE YEAR STOCK
4/ LESS THAN TWO YEAR STOCK
5/ LESS THAN TEN YEAR STOCK
6/ NO ASSETS FOR 10 ITEMS

FIGURE 2

generating the remainder. A second responded by referring to previous interrogations which had requested similar information for 83 tubes declared non-procurable previously. Some of these tubes also appeared on the 136 tube list. Matching the incomplete responses to previous correspondence resulted in an inordinate amount of time being spent compiling and evaluating the responses. The third department partially responded months late. The results were unexpected. Applications ranged from obsolescent test equipment to first line military weapons system hardware. There was no discernable pattern of use trend toward equipment obsolescence, or plan for orderly equipment replacement.

Demand Forecast Adjustment Factor

The group attempted to test the ability of the Military Department and civil agencies to provide data useful in developing demand adjustment factors. Two samples were distributed. The first consisted of a purged list of the original non-procurable tubes. The second consisted of a list of tubes selected as being likely to become the next "non-procurable" tubes because they (a) were manufactured by only one remaining manufacturer, (b) and were of limited demand and (c) were in a minimal asset position.

The form used to conduct this survey is shown in Figure 3. Figure 4 is an excerpt from the instructions that were mailed with the survey form.

Although there was some information furnished for individual end item applications, the overall response was disappointing. A summary of the information was developed and a display constructed. This display is included as Appendix 5.

VACUUM TUBE INQUIRY

FSN	U/1	U/C	SV	CURRENT MONTH		CURRENT QUARTER		QTR. 1 PREV.	
				QTY	FREQ.	QTY	FREQ.	QTY	FREQ.
5960-060-6562 (5844)	EA	1.50	AF	5	2	4	2	130	18

TURN AROUND DATA:

A. PHASE OUT CALENDAR YEAR OF LAST EQUIPMENT REQUIRING TUBE

B. CURRENT ANNUAL DEMAND ________________

C. CURRENT ON-HAND ASSETS ________________

D. PROJECTED ANNUAL DEMAND THROUGH PHASE OUT CALENDAR YEAR (REQUIRE NUMBER OF ENTRIES FROM PRESENT TIME THROUGH PHASE OUT YEAR)

CURRENT YEAR	+ 1 ________	+ 6 ________
	+ 2 ________	+ 7 ________
	+ 3 ________	+ 8 ________
	+ 4 ________	+ 9 ________
	+ 5 ________	+ 10 ________

USAF PREVIOUSLY COULD NOT VALIDATE A REQUIREMENT

FIGURE 3

VACUUM TUBE INQUIRY

Transmittal Letter Instructions Included:

> "FOR THOSE TUBES WITH MULTIPLE APPLICATIONS, PLEASE PROVIDE FOR EACH FEDERAL STOCK NUMBER, A PROJECTED TOTAL DEMAND FOR EACH YEAR THROUGH THE EXIT YEAR OF THE LAST SURVIVING EQUIPMENT."

FIGURE 4

Manufacturing Source Survey

Concurrently with the activity and surveys within government, the group sponsored a survey to update manufacturing source information for receiving tubes. This survey was conducted by the DESC procurement directorate. All known domestic tube manufacturers were asked to indicate which of the tubes in a list of 1640 tubes they could currently manufacturer. As shown in Figure 5, 241 of 941 receiving tubes are reported as having no current manufacturing source. However, not all 241 tubes will be in a buy position in the foreseeable future.

MANUFACTURING SOURCE SURVEY

NUMBER OF TUBES WITH:	
TWO OR MORE MANUFACTURERS	327
ONE MANUFACTURER	373
NO MANUFACTURING SOURCE	241
TOTAL	941

FIGURE 5

Group by Manufacturing Characteristics

An engineering study was undertaken to attempt to match groups of tubes with specific tube manufacturing facilities. This information would be of use in considering government owned or subsidized receiving tube manufacturing facilities.

The dominant piece of equipment is the Sealex machine. This machine accepts a raw bulb and interior tube assembly and automatically evacuates and seals the electron tube. Each bulb diameter requires a different size Sealex machine. All of the other fabrication and assembly operations are conducted on small free standing special purpose machines or bench type such as foot operated kick presses. With a Sealex machine installed, a manufacturer could generally fabricate or purchase all needed components for the tube and design and fabricate the necessary test equipment. Although ready avail= ability of all needed parts and materials can no longer be assumed, never- theless, the Sealex machine continues to be the determining element. Con- sequently a facility could be operated which would have the capability of making all of the tubes which could be accommodated in a Sealex machine and for which parts, the machinery, and materials necessary to fabricate them are still available.

This study indicated that receiving tubes generally fall into seven glass bulb categories, another for metal and ninth for all miscellaneous tubes, Figure 6. (A listing of the tubes in each group is available. It is too voluminous to be included in this report.) This study was intended to determine the technical feasibility of the concept, not the economic viability. The latter has not yet been addressed in specific terms. In conjunction with the overall manufacturing grouping survey, the Naval Ammunition Depot (NAD) Crane, Indiana, was asked to report on its ability to produce limited quantities

MANUFACTURING CHARACTERISTICS GROUPS

	BULB TYPE	NO. OF RECEIVING TUBES
I.	T-3	112
II.	ACORN	8
III.	T-5 1/2	149
IV.	1-9	239
V.	LARGE "T" BULBS	112
VI.	ST BULBS	88
VII.	METAL	67
VIII.	SPECIAL	16
IX.	T-6 1/2	205
		996

FIGURE 6

of receiving tubes. The NAD Crane does have a capability and mission to rebuild high value electron tubes. It does not have the capability to economically produce in volume quantity, relatively inexpensive receiving tubes. No economic justification has yet been developed to demonstrate that a government receiving tube manufacturing facility at the NAD Crane would be more cost effective than subsidizing existing contractor owned and operated facilities. A government tube plant would also raise the question of assuring life, quality and performance characteristics equal to that already demonstrated by existing tube manufacturers.

FINDINGS

1. The DVTSG has found that the allegations setting forth the situation in government and industry were substantially ture.

Within Government:

Receiving tubes are not automatically identifiable in FSC 5960.

No central file of application data exists for each DESC managed NSN.

Reutilization philosophy is unresponsive to receiving tube needs.

There are no formal procedures for advance alert of all echelons for requisitioning DoD Components.

Credibility was lacking.

Parochial interests often resulted in reluctant cooperation.

Industry:

Prices are escalating as economies of scale are lost.

Parts availability problems are increasing.

Production base is declining rapidly as operations are being consolidated or plants shut down.

Corporate plans are not being released.

2. No single technical solution exists for ameliorating the effect of lack of production sources for receiving tubes. Each generic solution has one or more major obstacles which is not likely to be overcome in all instances. Eight generalized solutions and their drawbacks are shown in Figure 7. For each National Stock Number, the most economical action will depend on factors such as demand, end article application(s) and density, remaining operating life expectancy, non-recurring (start up) costs, etc.

3. No governing procedure exists for gathering the data required to determine the appropriate action(s) to undertake when the last manufacturing

POSSIBLE LONG RANGE "SOLUTIONS"

"ANSWER"	DRAWBACK(S)
SUBSTITUTION	ONE IS NOT ALWAYS AVAILABLE
PLUG IN SEMICONDUCTOR	HASTEN DEMISE OF REMAINING TUBE MANUFACTURERS: LOW VOLUME ITEMS NOT OF INTEREST TO SEMICONDUCTOR MANUFACTURERS
SUBSIDY	NO BASIS OR AUTHORITY
APPORTION MARKET	ANTI-TRUST
LAST BUY	NOT ALWAYS OFFERED, QUANTITIES NEEDED UNCERTAIN, MOBILIZATION IMPACT
REPLACE EQUIPMENT	HIGH COST; NO SYSTEM TO ESTABLISH PRIORITIES COMPLICATED BY MULTIPLE APPLICATIONS
SECONDARY SOURCES	UNCERTAIN QUALITY AND AVAILABILITY
GOVERNMENT FACILITY	NO POLICY; COMPONENT NOT ALWAYS AVAILABLE; HIGH COST; SKILLS LACKING;

FIGURE 7

source for needed receiving tubes has ended, or is about to end, production. There is no policy instrument, guidance or joint agreement as to the individual and collective responsibilities of affected agencies. Existing directives, regulations and instructions do not comprehensively address this problem. Some procedures, such as reutilization visibility thresholds, acceptance criteria for excess stock, and economic order quantity calculation requirements hinder, rather than help, affirmative action.

4. There is no management requirement for determining the remaining inventory life of the end article applications for most receiving tubes. In those cases where a format exists, many entries for end article life forecasts are inaccurate or are coded "indefinite." This provides no basis upon which to estimate remaining total life cycle quantities of needed tubes.

5. Current practices do not permit timely determination of end article application and the forecasted remaining life of equipment furnished in accordance with international security agreements. No central data bank exists nor is there any procedure for summarizing the total end article equipment density or quantity, condition, or forecasted remaining life. Responsibility for various facets of this support are scattered and timely responses to requests for materiel management information are not furnished.

6. Development of a central file to contain end item application data for <u>all</u> consumable items is not feasible at this time. Time and budget constraints limit this activity to selected consumable items only. It is possible to use current Military Standard Requisitioning and Issuing Procedures (MILSTRIP) to begin to build a data file of selected items at the DESC. This procedure is shown in the Diagram in Figure 8. Later, implementation of the Defense Integrated Data System (DIDS) will create a file space for 55,000 selected consumable items with integrated management at the Defense Logistics Services Center which could replace the DESC file.

PROPOSED INTERIM DATA BANK BUILDING PROCEDURE

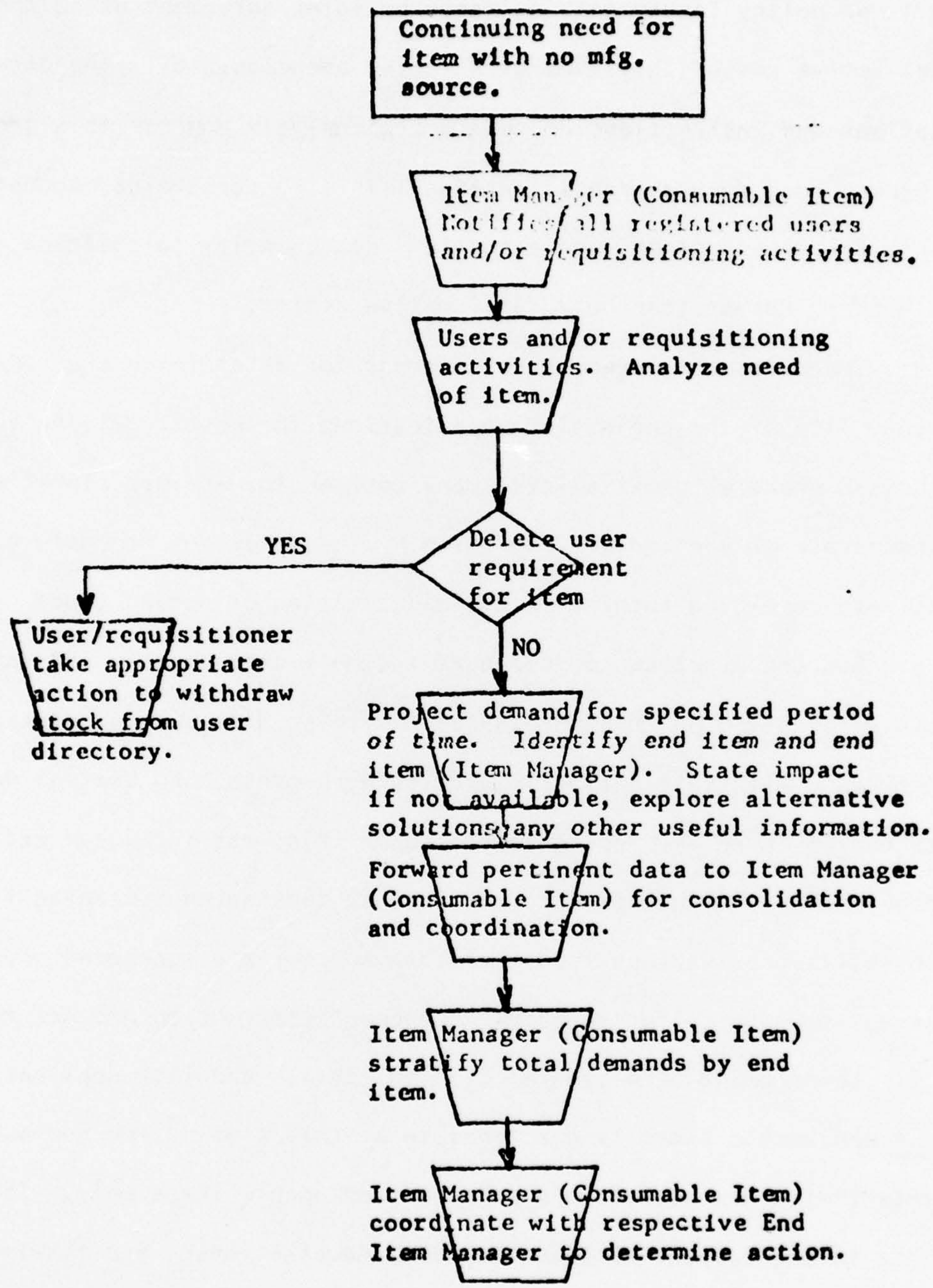

FIGURE 8

Recommendations

The following recommendations are divided into short term (completed within a year) and long term actions. Immediate direction and guidance are necessary to promptly begin to intensify efforts to ameliorate the impact of diminishing production sources for receiving tubes on the existing inventory of tube powered electronic equipment. A long range continuing program to improve and automate activities implemented in the short term should then be undertaken.

A. Short Term

1. Issue a DoD Directive specifying the responsibilities of the integrated manager and the requisitioning commands. The direction should contain guidance as to the specific actions and procedures the DSA and Military Departments should institute to implement the intent of the directive.

2. The Military Departments and the DSA should issue a joint implementing document specifying the responsibilities that each is to assume in order to solve any lack of manufacturing source problem for a consumable item. It may be possible to modify DSA Regulation 3200.1, Engineering Support for Items Supplied by Defense Supply Agency and General Services Administration. The new document should specify operating procedures for assuring timely liaison and coordination in the context of existing materiel management procedures.

3. Temporarily utilize "demilitarization" precious metal recovery program or other procedures to code selected National Stock Numbers to preclude disposal action until the integrated consumable item manager has been given the opportunity to claim excess for stock. An existing code could be redefined to include disposal procedures for items which must be recouped. This procedure could be an interim plan until a separate code

symbol is instituted to describe NSN's of nominal original value which may not be disposed of without the expressed approval of the integrated item manager because they are no longer obtainable at a reasonable cost.

4. A steering group should be convened to continue actions necessary to include in forthcoming automated materiel management procedures improved practices for dealing with situation of no manufacturing source for consumable items. Among the tasks this group would address are those longer range recommendations which follow.

B. Long Term

1. Consistent with product shelf life, develop and institute formal procedures for including "last buy" funds in "wholesale" stock fund budget process. This would permit a timely response to last buy opportunities now lost due to current lengthy budget planning procedures. Develop budgetary procedures to allow a subsidy for existing contractor owned facilities or develop guidelines for possible creation of a government owned production facility. (The latter action should be undertaken only after all other possible solutions have been exhausted.)

2. Create an end item application file for selected National Stock Numbers (NSN). Develop procedures for maintaining current information in this file and for purging from it those NSN's which are no longer of interest. Include in this file, a forecast by year of future density or quantity of each end article or latest date by which end article will be phased out of inventory. Develop associated procedures for the Engineering Support Activity to provide initial data and confirm or update at least annually. Develop priorities, if necessary, to determine either which equipment will receive remaining stocks of consumable items, or which end article equipments should be funded for replacement, or both.

3. Integrate improved procedures for dealing with problems of no manufacturing source into current and planned automated materiel management process. This entails all aspects of: (1) identifying problem consumable items; (2) notifying affected agencies; (3) developing and transmitting needed information; (4) assessing financial implications, schedule requirements, utility, and effect on military capability of alternative actions; (5) implementing the appropriate decision; and (6) notifying all affected of the action taken.